MIPP • Main Injector Particle Production Experiment • (FNAL - E907)

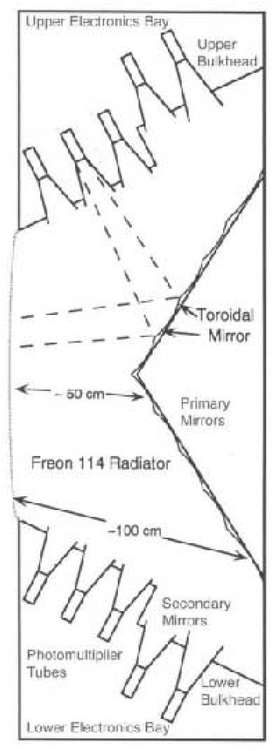
Beam Cherenkov

A set of two differential Cherenkov detectors will give positive identification of the beam particle, using the difference in the angle of Cherenkov light for particles of different mass at same momentum.

The head of one of the bem Cherenkov detectors.

Threshold Cherenkov

Using C_4F_{10} gas, the thresholds for π, K, and p are 2.7, 9.4, and 17.9 GeV, giving particle identification in the mid momentum range.



Side view of the Cherenkov threshold detector.

What is MIPP

The Main Injector Particle Production Experiment will measure the identities and momenta of particles produced in π+, π-, K+, K-, p, and $\bar{p}$ interactions on various nuclear targets and hydrogen as a function of beam momentum from 5 GeV/c - 120 GeV/c with high statistics. The beam will be generated using the 120 GeV proton beam from the Main Injector. This fixed target experiment is located in the Meson area in MC7. It was designed as a low cost experiment and uses mostly existing hardware. Data will be taken for ~2 years, starting in 2003.

Related Experiments

The MIPP experiment is unique in combining open detector geometry, large beam momentum range, and high statistics. The last open geometry experiment at MIPP beam energies was EHS, using a bubble chamber. The HARP experiment at CERN is currently taking data, but will cover energies up to ~15 GeV only. Data from single arm spectrometers is sparse and inherently has more systematic uncertainties.

MIPP Collaboration

Brookhaven National Laboratory • Y.Fisyak
EFI, University of Chicago • R.Winston
University of Colorado, Boulder • R.J.Peterson,
Elmhurst College and EFI • E.Swallow
Fermi National Accelerator Laboratory • W.Baker, D.Carey, J.Hylen, C.Johnstone, M.Kostin, H.Meyer, N.Mokhov, A.Para, R.Raja, S.Striganov
Harvard University • G.Feldman, A.Lebedev, S.Seun
Illinois Institute of Technology • P.Hanlet, N.Solomey, C.White
Indiana University • M. Messier
Lawrence Livermore Laboratory • D.Asner, P.D.Barnes Jr., J.Burward-Hoy, J.Gronberg, E.Hartouni, M.Heffner, S.Johnson, D.Lange, R.Soltz, D.Wright
University of Michigan • H.R.Gustafson, M.Longo, D.Rajaram, H-K.Park
Purdue University • A.Bujak, L.Gutay, D.E.Miller
University of South Carolina • T.Bergfeld, A.Godley, S.R.Mishra, C.Rosenfeld
University of Virginia • C.Dukes, L.C.Lu, K.Nelson, G.Niculescu

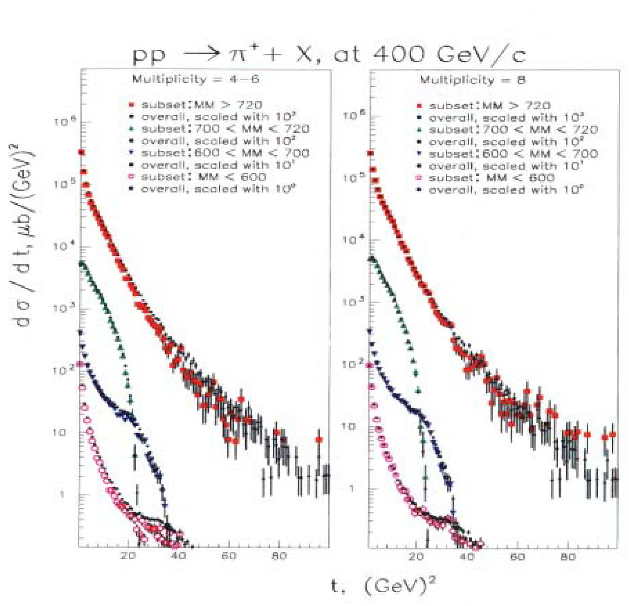
PHYSICS

Hadronic Fragmentation

A general law of scaling for inclusive reactions was proposed in 1978. It proposes that the ratio of the semi-inclusive to inclusive cross-sections is only a function of one Mandelstam variable M^2, mass squared (also known as s+t+u). The s (center of momentum energy) and t (momentum transfer squared) variables do not effect this ratio:

$$\frac{f_{subset}(a+b\rightarrow c+X)}{f(a+b\rightarrow c+X)} \equiv \frac{f_{subset}(M^2,s,t)}{f(M^2,s,t)} = \beta(M^2)$$

is only a function of M^2. This has been tested in limited cases. MIPP will test this scaling in much more detail.



t distributions for subsets in various M^2 ranges. Overall data weighted by the appropriate β_{subset} is superimposed on the subset data.

Light Meson Spectroscopy

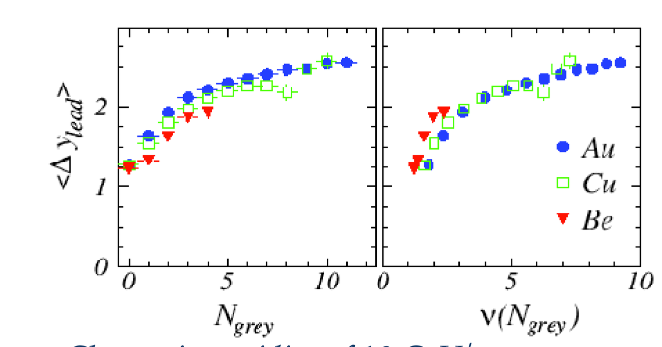
Some of the light mesons predicted by SU(3) and SU(6) symmetries have not been observed. With its large acceptance and particle identification capabilities MIPP will add to the existing data. Also MIPP will search for glue-balls (gg), quark gluon hybrids (qqg) and multi-quark assemblies like di-baryons (qqqqqq).

$N^{2S+1}L_J$	J^{PC}	$u\bar{d}, u\bar{u}, d\bar{d}$ I=1	$u\bar{d}, u\bar{u}, d\bar{d}$ I=0	$\bar{s}u, \bar{s}d$ I=1/2
1^1S_0	0^{-+}	π	η, η'	K
1^3S_1	1^{--}	ρ	ω, ϕ	$K(892)$
1^1P_1	1^{+-}	$b_1(1395)$	$h_1(1170), h_1(1380)$	K_{1B}
1^3P_0	0^{++}	$a_0(980)/a_0(1450)$	$f_0(400-1200)/f_0(980)/f_0(1370)$	$K_0^*(1430)$
1^3P_1	1^{++}	$a_1(1260)$	$f_1(1285), f_1(1510)$	K_{1A}
1^3P_2	2^{++}	$a_2(1320)$	$f_2(1270), f_2'(1525)$	$K_2^*(1430)$
1^1D_2	2^{-+}	$\pi_2(1670)$		$K_2(1770)$
1^3D_1	1^{--}	$\rho(1770)$	$\omega(1650)$	$K^*(1680)$
1^3D_2	2^{--}			$K_2(1820)$
1^3D_3	3^{--}	$\rho_3(1690)$	$\omega_3(1670), \phi_3(1850)$	$K_3^*(1780)$
1^3F_1	4^{++}	$a_4(2040)$	$f_4(2050), f_4(2200)$	$K_4^*(2045)$
2^1S_0	0^{-+}	$\pi(1300)$	$\eta(1295)$	$K(1460)$
2^3S_1	1^{--}	$\rho(1450)$	$\omega(1420), \phi(1680)$	$K^*(1410)$
2^3P_2	2^{++}		$f_2(1810), f_2(2010)$	$K_2^*(1980)$
3^1S_0	0^{-+}	$\pi(1770)$	$\eta(1760)$	$K(1830)$

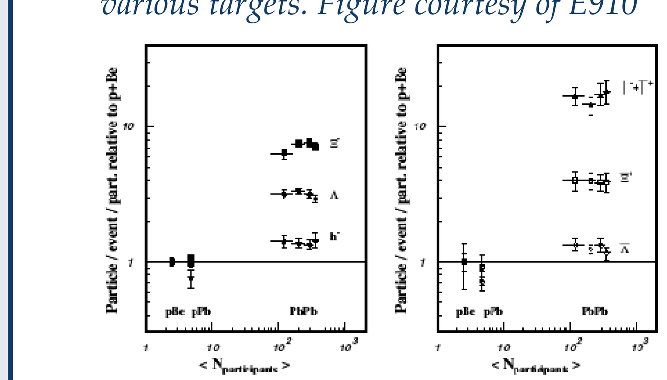
Current status of meson multiplet assignments taken from the PDG "Review of Particle Physics".

Relativistic Heavy Ion Physics

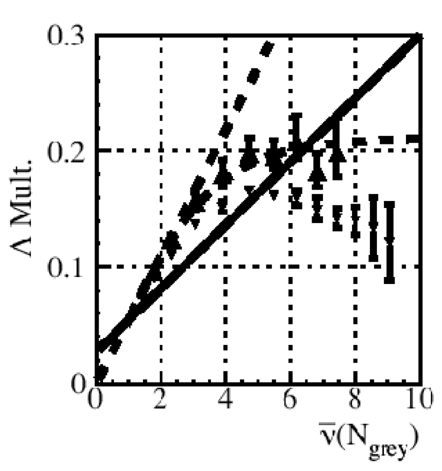
The physics of pA collisions is important for heavy ion collisions because it is essential to understand the nuclear medium and multiple collision effects. A measurement of strangeness production per participant in pA collisions will 'calibrate' the strangeness enhancement seen in AA collisions at CERN, often cited as QGP evidence. MIPP, a fixed target experiment, provides acceptance in the beam direction, which is often lacking in collider experiments.



Change in rapidity of 18 GeV/c protons as a function of the number of recoil nucleons for various targets. Figure courtesy of E910



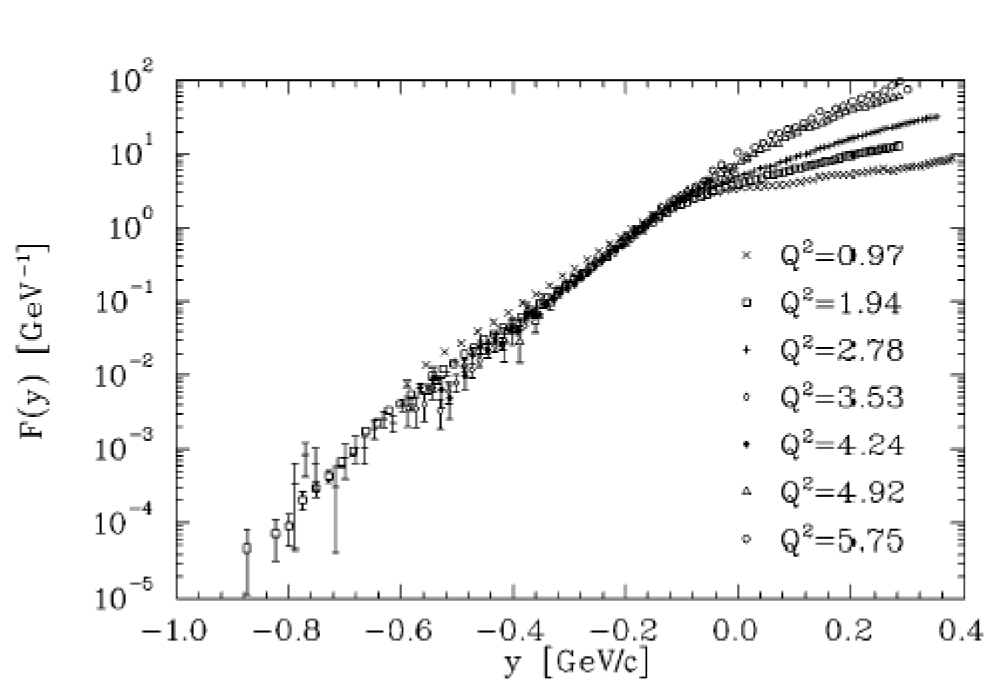
Data from the SPS experiment WA97 showing various strange baryon yields per participant relative to pBe collisions.



Dependence of Λ production on the number of recoil nucleons in 17.5 GeV/c pAu collisions from the E910 experiment. Soild points show yield within E910 acceptance, open points show estimated total yield. Solid line shows participant scaling of pp data, dot-dashed shows maximal "binary-collision" scaling. Dashed line is an empirical fit to the data

Nuclear Scaling

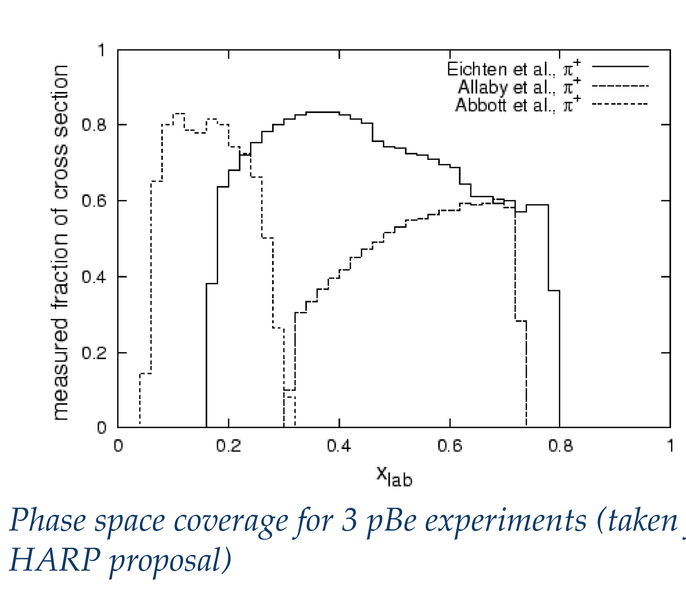
Scaling in y will be tested at MIPP for hadron nucleus scattering. y maybe thought of as the component of the struck nucleon's momentum along the direction of the momentum transfer. The scaling function is independent of q^2 and represents the nuclear momentum distribution. y scaling is verified in ep scattering and has been tested with low energy hadron beams at the KEK E352 experiment.



Scaling function F(y) for Fe. The Q^2 values are given for Bjorken x = 1

Service Measurments

Atmospheric neutrino experiments will use the cross sections of pions and protons on nitrogen and oxygen to determine the neutrino energy spectrum and overall flux. The normalization uncertainty can be reduced from the 15%-30% level down to a few percent.



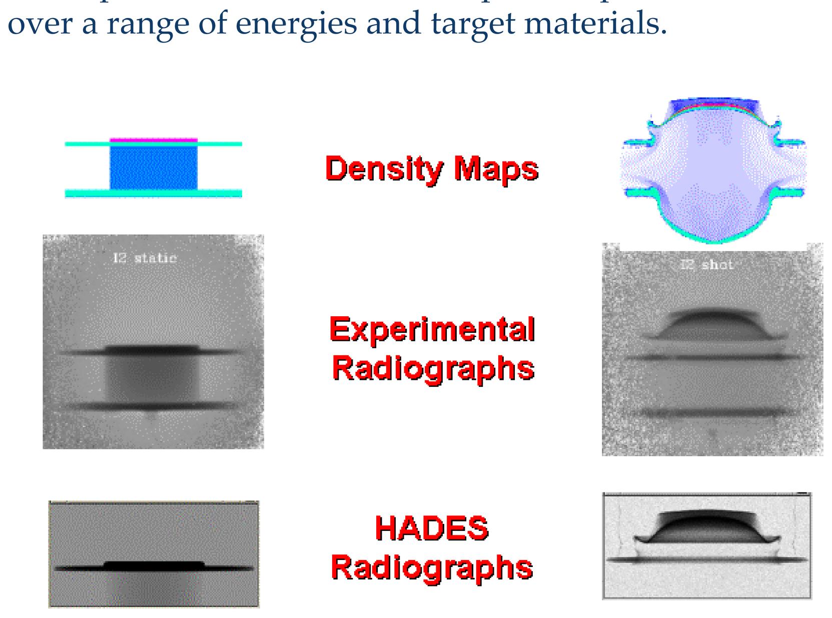
Phase space coverage for 3 pBe experiments (taken from HARP proposal)

Collider experiments benefit indirectly. The MIPP cross sections will make GEANT4 more precise than approximate models used now.

Minos needs to measure the particle spectra of Main Injector beam on the NuMI target to predict the Neutrino energy spectrum in the far detector. This will reduce systematic errors compared to Monte Carlo models of the NuMI target based on incomplete data sets.

Neutrino factory/Muon Collider target measurements can be done at MIPP.

Proton Radiography, the imaging of an object by passing protons through it, relies on good knowledge of the proton cross-sections and particle production over a range of energies and target materials.



Experimental proton radiographs compared to simulations of the same setup. Left: static case; right: time slice of the of the same system while expanding from detonation. (courtesy of Hopyard Experimental Team)

Fermilab